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ABSTRACT

Piaget's theory of cognitive development is explained, especially in relation to the teaching of elementary school science. Several research projects involving Piaget's theories are reviewed. (MLR)

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Piaget's Work: A Consideration for Science Education

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Over fifty years of hard work, research, writing, and introspective study have been provided by Jean Piaget and his associates. Piaget has established himself as the premier psychologist in the area of children's intellectual development. David Elkind refers to him as "the giant" in his field, comparable to Freud in psychoanalysis.[1]

The author makes no pretense in claiming expertise in understanding the full measure of worth of Piaget's life work. Elkind has indicated that it may well be another fifty years before all of the research efforts surrounding Piaget's ideas are fully evaluated and meaningfully interpreted. At best, only a glimpse of what effect Piaget's work should have on classroom practices can be obtained now. When attempts are made to translate his ideas into constructive pedagogy, at least two problems of significance immediately appear: (1) Piaget's own writings are very difficult to comprehend, especially because of the unique terminology employed, and (2) his concern is not with learning or instructional theory, but with a theory of development.

When dealing with the first of these two problems, most educators resort to reading translations or interpretations of Piaget. Although this is not necessarily a serious situation, the readers are still one step removed from the original data and the interpretations of these data. Some authors have misinterpreted or misapplied Piaget's meaning, but this problem has been rectified to some extent by a continuous flow of special conferences which have focused entirely on what Piaget has said and what this means regarding practical

decisions in education. Several such efforts have resulted in Piagetian Societies or Associations which have held annual conferences for the past half-decade. A considerable number of doctoral theses have focused on Piaget's theory of child development and its implications to educators. Obviously, few men have generated such an intense interest in their ideas in the academic community.

The second major problem which was identified is of greater importance and provides greater difficulties for practicing educators. Piaget's theory is a developmental theory. Exactly what that means becomes problematic in and of itself, but it is clear that he has not attempted to develop instructional prescriptions. Ideas which are directly related to what a teacher does in a classroom are generally referred to as learning or instructional theories, with preference being given to the latter term. Piaget studies intellectual development as a biologist might study physical development or growth. In fact, his developmental studies of human intellectual capabilities and capacities stand alone. No one else has studied the development of knowledge, which Piaget describes as a spontaneous process tied to embryogenesis and concerns the development of the body, the nervous system, and mental functions.[2] Learning, he argues, is just the opposite, for it is provoked by situations and is a limited and more narrow process.

In an attempt to define development, Piaget has listed four factors which are involved:

1) <u>maturation</u>: insufficient by itself to explain development; the ordering of stages in mental growth is constant, but the

chronological ages at which these stages appear varies greatly. (For a brief description of these developmental stages, see pages 4 and 5.)

2) experience: a basic factor in the development of cognitive structures, but, again, an insufficient explanation of development by itself; Children, Piaget implies, can only receive valuable information via language or education if they are in a state where they can comprehend it and this requires a mental structure available for assimilation.

3) linguistic transmission: this again involves a "mental readiness" for comprehension to occur. For example, children can't comprehend the statement "Some of my flowers are roses" until they develop the concept of a subclass within a class. This phrase would mean the same as "all of my flowers are roses" to children lacking this conceptual frame of reference.

4) equilibration: this involves the ability to compensate for an action in one direction by an operation in another direction, and it probably is developed in stages or levels. For example, a ball of clay rolled into a sausage shape will be judged as "bigger" or "more" by young children and as they cognitively grow they will later judge this change in shape as having no effect on the amount of clay.

Development is therefore a complex phenomena that cannot be easily defined. Obviously, if it is difficult to define, it is even more difficult to monitor and comprehend. Nevertheless, what Piaget and his associates have discovered thus far can be of some immediate value for teachers, but it can also be inferred that the future impact of his work will be enormous.

The reader is again reminded that Piaget is not interested in pedagogy and he is not especially interested in the application of his ideas in a classroom environment. He is interested in how children learn and not how children should be instructed. He is interested in extending man's knowledge, not his pedagogy.

TABLE 1

PIAGET: INTELLECTUAL DEVELOPMENTAL STAGES - Summary

Developmental Stage	Age Range	Characteristics
Sensorimotor	0 - 1 1/2	Pre-verbal - no language; object is "real" only when it is in the perceptual field; learns to perceive and identify objects; hidden objects located through random searching; time=present; space=immediate; some distinctions made - parents, animals, names; some sense of direction and purpose.
Preoperational	1 1/2 - 7 or 8	Organized language begins to develop Egocentric Perceptually oriented, no abstract thinking, no logical progression in thought, can't reason by implication Simple goal-directed, static thinker - doesn't think in terms of a series of operations Lacks ability to coordinate variables, deals with single rather than multiple characteristics of an object May be satisfied with contradictory formulations Time - past and future also, but limited Space - more immediate environment: home yard, neighborhood, etc. No concept of conservation - lacks operational reversibility in thought and action
Concrete Operations	7 - 8 to 11 - 12	Thinking is concrete, not abstract - child can perform simple logical operations, classify and determine relationships (such as serial ordering) Combining, ordering, separating, seriating, multiplying or repeating, dividing, reversible thinking Concepts of conservation develop (first length, next matter, then weight, and

(Continued next page)

TABLE 1 (Continued)

		finally volume Concept of reversibility develops, but inversion and reciprocity are not integrated into a single system Awareness of variables, classifies, measures
Formal Operations	11-12 to 14-15	Stage of formal thought (abstract thinking) Reflective thinking - can evaluate own thinking processes Ability to perform controlled experiments, identifying and controlling variables Synthesizes - imagines - Questions ethics Understands probability Reversal of direction between reality and possibility (variables are hypothesized before experimentation); Discovers that a single variable can be isolated to analyze its role or the roles of associated factors

Even though Piaget is not trying to construct a theory of instruction, his work does contribute, sometimes rather directly, to our knowledge of how to properly teach children. One shortcoming of this knowledge, however, is that it is typically specific and therefore can best be applied only to specific tasks. For example, if a child doesn't conserve length, we would know that it would be a waste of time trying to teach him how to measure things with a ruler. Because the conservation of length precedes the development of conservation of matter, weight, and volume, we would also know, or at least be able to infer, that tasks involving these areas would also be inappropriate in the curricular planning for this child. The teacher would not expect to have success teaching this particular child to order objects by weight or demonstrate relationships of pints to quarts to gallons. If, however, a teacher in an elementary school would list the hundreds, or is it thousands, of concepts which children are expected to learn, it is probably true that Piaget's theory would speak directly to a relatively small percentage of these concepts.

To a casual reader it may appear that the author is about to conclude that Piaget doesn't have much of immediate value to offer educators. It is true that in order to incorporate Piaget's ideas into curriculum planning, we must infer, speculate, and interpret, and we must consequently hope that our judgments are sound, but it also seems to be true that we would in all probability make a far greater number of curricular blunders if we would ignore Piagetian theory. Bluntly stated, we will make instructional errors, both in planning and in implementing our plans, but attempting to apply Piaget's ideas

in a general context should produce fewer errors and therefore result in better instruction. A little truth should carry us farther than a reliance on blind intuition and speculation.

Several prominent science curriculum projects, such as SCIS and ESS, have implemented Piaget's theoretical ideas about how children develop intellectually. This is merely mentioned to support the notion that his theory has been accepted and used for practical purposes by prominent curriculum development groups.

Even though a specific, detailed knowledge of the developmental stages identified by Piaget may be absent, the application of one generalization seems to be appropriate for improving classroom instruction and assisting children to learn. Simply stated, students in elementary and junior high school will learn best if they are given opportunities to encounter real or concrete experiences rather than abstract and verbal experiences. If Piaget's research is adequate, it indicates that language and thought are different systems and develop at different rates. David Elkind stated that what impressed him the most about American education, at all levels, is its extreme verbalism. He continued by indicating his contention that language had been given exaggerated importance in the elementary school curriculum.[3] Dewey had recommended many years ago that schools should emphasize "doing" rather than "telling." Piaget has provided more evidence to support this view which is now buttressed by more sophisticated research. Piaget's research indicates that emphasizing concrete experiences in which children encounter real materials is more than just another instructional recommendation for improving classroom instruction,

but it is essential if young students are going to learn anything in a meaningful and lasting way. Verbalizing instruction for children from kindergarten through junior high school does not appear to be the most effective and efficient means of initiating significant learning. The ability to think abstractly is absent from almost all of the age groups found in pre-high school classrooms, and concrete experiences are needed. Research has even shown many high school students to be incapable of abstract thought.

Renner and Stafford administered a variety of tasks to 588 students in grades 7-12.[4] The purpose of their study was to determine the mental operations classification of the students. Piaget has suggested that formal operations, the ability to do abstract thinking, should normally begin around the age of 11 or 12 and be rather firmly established by the age of 14 or 15. A brief examination of Tables 2 and 3, however, shows that the vast majority of these students are not primarily functioning at an abstract level. Seventy-five percent are identified as preoperational or concrete operational, and, according to Renner and Stafford's own critique, only 14 students were fully formal operational. This is only slightly more than 2%, and when the amount of verbal, abstract instruction which these 588 students probably receive is contemplated, these results become dramatic, if not depressing. We simply don't typically instruct students in the most efficient and effective ways, and their need for concrete experiences is probably not being satisfied in a reasonable and significant way. Faced with a preponderance of abstract instruction, the students are not only being ineffectually taught, but are likely to be frustrated and many may judge their abilities as inadequate, when, in reality, their instruction

TABLE 2

Score	Grade 7	8	9	10	11	12	Totals
0-5	5	3	4	4	3	1	20
6	8	5	5	6	5	3	32
7	11	20	10	9	6	0	66
8	23	16	12	19	16	3	89
9	13	13	12	9	14	15	76
10	15	20	19	11	13	19	97
11	5	7	16	11	11	13	63
12	8	9	4	10	13	6	50
13	5	9	3	5	6	9	37
14	2	3	6	5	4	6	26
15	0	1	1	3	5	8	18
16	1	2	2	2	3	4	14
	n=96	n=108	n=94	n=94	n=95	n=97	n=588

TABLE 3

Score	Classification	Number of Students
0-5	Preoperational	20
6-11	Concrete operational	423
12-13	Post-concrete operational	87
14-16	Formal operational	58

Taken from: Renner, Stafford, and Ragan, Teaching Science in the Elementary School, 2nd Edition, Harper and Row, New York, 1973, page 345.

is psychologically inadequate. This problem is magnified in grades K-6, and can only be corrected with a maximum effort toward instruction which involves concrete materials.

Table 4 provides additional data which relates to the mental development (growth) of elementary school children. It projects the development of conservation tasks, and illustrates the variable pattern in which these abilities or capacities emerge. Note, for example, that there were three 10-year olds who didn't conserve number. What a frustrating experience arithmetic instruction must be for them. Four 11-year olds don't conserve length, and measurement tasks must be equally frustrating for them. In addition to merely providing interesting information, this table also helps us to comprehend the need to gather such data about students if we are going to provide instruction that is of value to the individual as opposed to the group. Perhaps, at this point in time, Piaget tells us more about what not to do than he offers prescriptions for what we should do. If a child, for example, does not conserve number, we may not know exactly what instruction would be best for him, but we do know that teaching addition, subtraction, multiplication, and division would be inappropriate and frustrating. Neither does it appear to be "fair" to identify such a student as stupid and award him an "F" in mathematics.

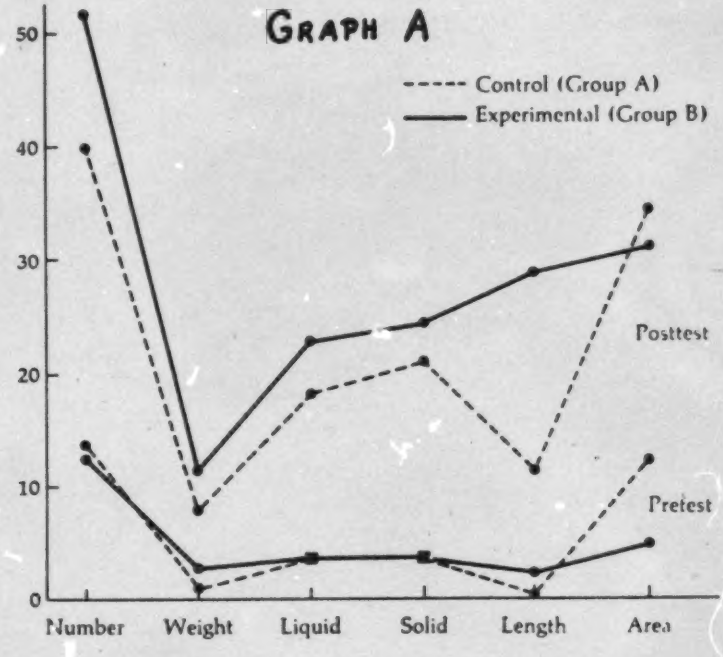
Stafford and Renner additionally cite some evidence that certain concrete experiences may assist some children in developing conservation. An experimental group of 60 children received identical instruction with the exception of being exposed to a unit of instruction from the Science Curriculum Improvement Study, Material Objects. Students who used these materials worked with

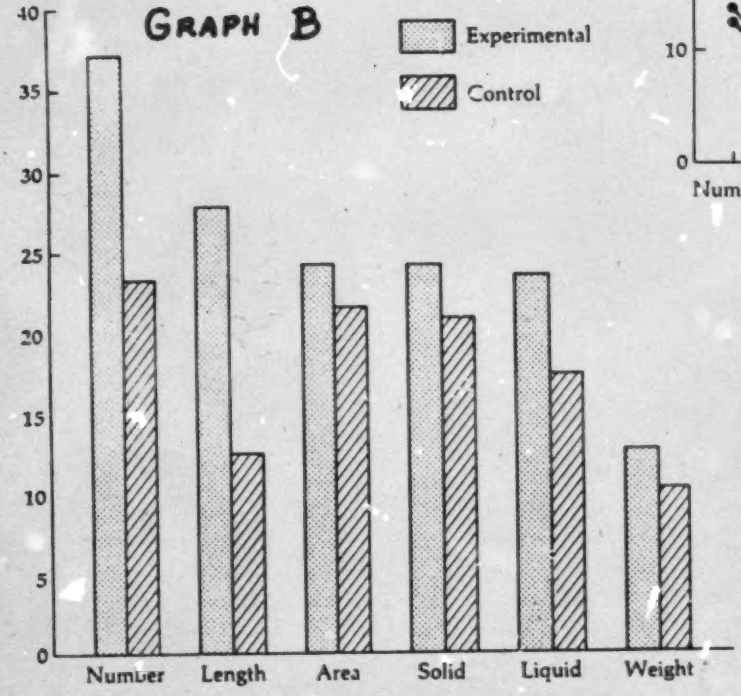
TABLE 4

Age - Months	Sample Size	Number	Solid Amount	Liquid Amount	Length	Area	Weight
60-64	12	3	2	2		1	1
65-68	12	7	2		2	2	3
69-72	12	6	3	4	1	2	1
73-76	12	8	7	7	3	6	3
77-80	12	8	6	5	3	2	6
81-84	12	9	5	5		3	5
85-88	12	11	11	9	6	9	10
89-92	12	11	9	11	9	8	11
93-96	12	9	9	8	7	6	8
97-100	12	12	12	11	9	8	11
101-104	12	12	11	8	5	7	8
105-108	12	11	9	9	7	8	10
109-112	12	11	10	10	7	7	6
113-116	12	11	11	10	7	7	7
117-120	12	12	12	10	7	6	9
121-124	12	9	12	11	7	8	9
125-128	12	11	11	10	9	7	11
129-132	12	12	11	11	12	10	10
133-136	12	12	12	12	8	7	12
137-140	12	12	10	10	10	10	12
141-144	12	12	12	12	12	12	12

Taken from: Renner, Stafford, and Ragan, Teaching Science in the Elementary School, 2nd Edition, Harper & Row, New York, 1973, p. 395.

a variety of common objects and studied their properties. By observing Graph A, it can be determined that between September, 1968 and January, 1969 both groups of children greatly increased their capacities to conserve number, weight, liquid, solid, and area. In every task except the conservation of area, the experimental group had more children conserving than did the control group. If we consider the real increase within each group to conserve, as shown in Graph B, we find that the experimental group exceeded the control group on every conservation task evaluated.





It is difficult to infer exactly what was responsible for the increased ability to conserve for both groups during this period of about six months. Perhaps it was basically maturation, or school related experiences, or experiences outside of school, or maybe it was a combination of these factors. Nevertheless, it also appears that the concrete experiences available in "Material Objects" did contribute to the development of conservation skills in some children. If nothing else, we at least have another "speck" of evidence which supports the "learning by doing" hypothesis.

It is probably evident by now that directly applying Piagetian theory to classroom practices involves philosophy as much as it involves scientifically supported evidence. With this thought in mind, the author would like to share a few observations which have been made by Albert Szent-Gyorgyi, a prominent research biologist. The following quotations have been taken from one of his papers, "Teaching and Expanding Knowledge."[5]

> . . . first, about the main instrument of teaching: books. Books are there to keep the knowledge while we use our heads for something better.
>
> The time spent in school is relatively short compared to the time thereafter . . . most of us have to learn all of our lives, and it was with gray hair that I took up the study of quantum mechanics . . . so what the school has to do, in the first place, is to make us learn how to learn, to whet our appetites for knowledge, to teach us the delight of doing a job well and the excitement of creativity . . .
>
> It is a widely spread opinion that memorization will not hurt, that knowledge does no harm. I'm afraid it may. Dead knowledge dulls the spirit, fills the stomach without nourishing the body. The mind is not a bottomless pit, and if we put in one thing we might have to leave something else out. By a more live teaching, we can fill the soul and reserve the mind for really important things.

These quotations were presented for two reasons: one, Szent-Gyorgyi has the ability to express the author's own opinions in such a delightful way that it would be extremely difficult to improve the verbage, and, two, it is interesting to note that he desires schools to provide a kind of instruction that corresponds closely to the prescription that could be written from Piaget's findings. The common sense logic of Szent-Gyorgyi appears to find imperative support in the research of Piaget.

Piaget says that elementary school children need concrete experiences for significant learning to occur. Szent-Gyorgyi indicates that concentrating on learning from books, memorizing, and cramming the head with knowledge will dull the spirit of the learner and not assist him in learning how to learn, which he sees as a noble goal. Dewey said that "children learn by doing" over fifty years ago. Many others could justifiably be quoted who support these notions, but, perhaps more than anyone, Piaget has given us some hard data which helps change these philosophically derived recommendations to scientifically supported inferences. Hopefully, these inferences of today will be refined and become tomorrow's conclusions.

Even though Piaget's work will probably never end, this paper must. No one could adequately treat fifty years of research and work in a short discussion such as this. However, a loose interpretation of Piaget's work would provide at least tentative support for the following recommendations which, if applied by a classroom teacher or curriculum developer, would almost certainly improve the teaching-learning environment for children and young adults.

1) Children are not minature adults and therefore verbal teaching strategies which may be productive with adults are usually too abstract to be useful when used with children.

2) Children develop or grow mentally in a way that parallels physical growth. It is therefore no more appropriate to force mental tasks upon them that they are not mentally mature enough to handle than it would be to insist that they be required to lift unmanageable weights.

3) If the developmental stages of children vary for identical chronological ages (as does physical growth), it seems to be highly unfair, if not ridiculous, to provide all of them of a certain chronological age with the same instruction and then judge their performance on a basis of comparisons made within the group.

4) If children are accepted as adequately endowed mentally and instruction is patterned to their developmental level, then all children will be successful learners. Additionally, in the author's opinion, success breeds success and increases the motivation to continue learning.

5) Children in classrooms where reading and talking predominate will learn less than those in classrooms where children continually interact with materials.

6) Working successfully with materials must be rewarded at least as highly as working with words. Working with materials but evaluating and judging with words will become self-defeating.

7) Piaget has provided added support to the notion that all children are different. Perhaps it is time to believe it.

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